Pediatrics and Neonatology (2016) xx, 1–7

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: http://www.pediatr-neonatol.com

ORIGINAL ARTICLE

Quality Improvement of Nasal Continuous Positive Airway Pressure Therapy in Neonatal Intensive Care Unit

Chien-Yi Chen [a], An-Kuo Chou [b], Yu-Lien Chen [c], Hung-Chieh Chou [a], Po-Nien Tsao [a], Wu-Shiun Hsieh [a,*]

[a] *Department of Pediatrics, National Taiwan University Children Hospital and National Taiwan University College of Medicine, Taipei, Taiwan*
[b] *Department of Pediatrics, National Taiwan University Hospital, Hsin-Chu Branch, Taipei, Taiwan*
[c] *Department of Nursing, National Taiwan University Children Hospital, Taipei, Taiwan*

Received Jan 13, 2016; received in revised form Apr 13, 2016; accepted Apr 25, 2016
Available online ■ ■ ■

Key Words
infants;
nasal continuous positive airway pressure;
nasal trauma;
protocol

Background: Nasal continuous positive airway pressure (NCPAP) therapy is widely used in neonates, but the clinical practice varies. However, nursing practice differs among individuals, and an inappropriate application method may delay the respiratory therapy, influence the beneficial effect of NCPAP, and increase complications. We introduced a quality improvement project to expedite the application of NCPAP therapy and decrease the incidence of nasal trauma.

Methods: A new strategy of mobile NCPAP cart with prepacked fixation kits and a written protocol was implemented from April 2006. All medical staff answered a questionnaire to assess their basic knowledge before and after intensive training. The records of the patients who were treated with NCPAP from October 2005 to November 2006 were reviewed.

Results: Fifty-nine medical staff were involved in the project, and their mean score for the questionnaire improved from 69.2 points to 98.3 points after training. From October 2005 to November 2006, 113 infants were recruited in total and 82 of them were admitted after the protocol was implemented. The NCPAP cart dramatically shortened the preparation time (from 520 seconds to 72 seconds) and the application time (from 468 seconds to 200 seconds). The use of the nursing protocol significantly decreased the incidence of nasal trauma in the study population (45.2% vs. 19.6%, $p = 0.006$), but not in infants with a birth weight of < 1000 g. Risk factors for nasal skin trauma included lower gestational age and birth weight, longer duration of NCPAP use, and lack of standardized nursing care.

* Corresponding author. Department of Pediatrics, National Taiwan University Children Hospital and National Taiwan University College of Medicine, Number 8, Chung-Shan South Road, Taipei 100, Taiwan.
E-mail address: hsiehws@ntu.edu.tw (W.-S. Hsieh).

http://dx.doi.org/10.1016/j.pedneo.2016.04.005

Please cite this article in press as: Chen C-Y, et al., Quality Improvement of Nasal Continuous Positive Airway Pressure Therapy in Neonatal Intensive Care Unit, Pediatrics and Neonatology (2016), http://dx.doi.org/10.1016/j.pedneo.2016.04.005

Conclusion: The mobile NCPAP cart with prepacked fixation kits is a practical way of expediting the initiation of NCPAP therapy. The written nursing protocol decreased the incidence of nasal trauma in infants, except for those with an extremely low birth weight.

1. Introduction

Nasal continuous positive airway pressure (NCPAP) is the most common method of respiratory support in neonatal intensive care units (NICUs). Several multicenter randomized controlled trials demonstrated that NCPAP was an effective alternative for preterm infants as initial respiratory management.[1–3] Early application of NCPAP, within 5—15 minutes after birth, can reduce the need for intubation, mechanical ventilation, and surfactant use in preterm infants with respiratory distress.[1–4] The American Academy of Pediatrics recently recommended that using NCPAP immediately after birth with subsequent selective surfactant administration may be considered as an alternative to routine intubation with prophylactic or early surfactant administration in preterm infants.[5]

Although an early application of NCPAP is beneficial to infants with respiratory distress, there are only a few documented protocols addressing the practical setup process step by step, especially in preterm infants.[6,7] Nursing practice varies among NICUs and individuals, and an inappropriate application method may delay the respiratory therapy, influence the beneficial effect of NCPAP, and increase complications. To improve the care quality of NCPAP therapy in infants with respiratory distress, we introduced a quality improvement project conducted by a team including neonatologists, nursing staff, pediatric residents, and respiratory therapists. The major aims were to develop a written NCPAP nursing protocol, reduce unwanted variation in clinical care, shorten the NCPAP set time, increase patient comfort during NCPAP therapy, and decrease the incidence of complications, especially nasal trauma.

2. Methods

2.1. NCPAP therapy

Our hospital is a 2000-bed teaching facility providing tertiary care in northern Taiwan. It has a Level III NICU with a total of 25 beds. From October 2005 to November 2006, there were 369 admissions to the NICU. Around 177 (48%) patients were admitted due to respiratory distress, and in 66% of them NCPAP was used for respiratory support. NCPAP therapy has been used in our NICU since 1989, and it has been the first-line therapy for all infants with respiratory distress requiring postextubation support. Both ventilator and bubble NCPAP were used, but only ventilator NCPAP (Infant Star 500; Infrasonics Inc., San Diego, CA, USA, or Babylog 8000; Drager, Lubeck, Germany) was used as initial respiratory support. The flow ranged from 5 L/min to 10 L/min, and the positive end-expiratory pressure setting was kept at 5 cmH_2O.

2.2. Training

Basic knowledge of NCPAP among medical staff is associated with the successful application of early NCPAP therapy. All medical staff in our NICU, including nurses, neonatologists, pediatric residents, and respiratory therapeutics, were asked to complete a questionnaire to assess their basic knowledge about indications, mechanism, application, settings, contraindications, and complications. After the first evaluation, lectures and small group discussion were introduced to improve knowledge and increase communication among the medical staff. After the classes, the staff answered the questionnaire again.

2.3. Equipment preparation

Binasal Hudson prongs (Hudson Respiratory Care, Inc., Temecah, CA, USA) were the only type of prongs used, with size 0 fitting infants weighing $<$ 700 g and size 5 fitting infants weighing $>$ 3500 g.[6] To optimize the NCPAP delivery, prongs of the correct size should be chosen for each infant and secured properly. In addition to the prongs, other equipment must be prepared and assembled before application, including a snug, a fitting hat, Velcro, DuoDerm, and a tape. The Velcro and DuoDerm need to be clipped to the proper shape and size before use. All equipment was usually stored in stacks in the NICU, which had to be delivered to the bedside when NCPAP therapy was indicated. Preparation of prongs and securing staff took time, and increased the risk of using the wrong size equipment or having inappropriate securing. Thus, we developed a mobile NCPAP cart with different sizes of NCPAP fixation kits, which were prepared according to body weights (Figure 1). Five layers and 10 drawers were located on the top of the working cart. Each layer was designed for prongs of a particular size (ranging from size 0 to 4; size 5 is seldom used in the NICU), with easily identifiable labels. The left drawers stored three packages of NCPAP fixation kits (Figure 1A). The right drawers stored the precut DuoDerm and Velcro (Figure 1B). The main drawer of the cart stored other equipment required during the setup of NCPAP, such as tape, scissors, saline, swab, and extra uncut DuoDerm and Velcro. The different sizes of tubes were placed at the bottom of the cart, and a clamp for fixation of the tube hung over the side of the cart. The movable cart was designed to be transferred quickly to the bedside, to shorten the preparation time and decrease the frequency of delivering wrongly sized kits to patients requiring NCPAP therapy. The

Please cite this article in press as: Chen C-Y, et al., Quality Improvement of Nasal Continuous Positive Airway Pressure Therapy in Neonatal Intensive Care Unit, Pediatrics and Neonatology (2016), http://dx.doi.org/10.1016/j.pedneo.2016.04.005

Figure 1 Mobile NCPAP cart with different sizes of NCPAP fixation kits. (A) All of the components of one NCPAP kit, including a hydrocolloid patch, Velcro, one suitable cap, and a nasal prong. (B) Precut DuoDerm patches required for nasal prong sealing and fixation. The patch and holes were designed according to different body weights and prong sizes. (C) Mobile NCPAP cart. NCPAP = nasal continuous positive airway pressure.

preparation duration, from the beginning of collecting the equipment to all equipment being assembled correctly, was measured and recorded by research nurses before and after the NCPAP cart implementation.

2.4. Written nursing protocol

To shorten the application duration of NCPAP, a written NCPAP nursing protocol was implemented in our NICU from March 2006 (Table 1 and Figure 2). The protocol was modified from the protocol of Morgan Stanley Children's Hospital, New York, NY, USA, and it was introduced to medical and nursing staff in a clearly written document with easy-to-understand figures. The major points of the protocol are the use of nasal prongs of appropriate size and a structured method of fixation to increase the stability of nasal prongs in position. After April 2006, all patients admitted to the NICU and treated with NCPAP received this standard nursing care. The application duration, from the beginning of the application of nasal prongs to the correct positioning of patients and start of NCPAP therapy, was measured and recorded by research nurses before and after nursing protocol implementation.

2.5. Evaluation of nasal trauma

Care for nasal trauma was also standardized. The nursing staff examined the nasal cavity of infants who received NCPAP therapy every shift and recorded any significant change. If bleeding of the nasal mucosa was noted, unnecessary suctioning was prohibited to reduce mucosal injury, and topical antibiotic ointment was applied to the damaged area. If persistent hyperemia of the intact septal skin developed, the first step was to check the pressure source and remove it, if possible. If the condition deteriorated to an epidermal ulcer with abrasion, irrigation with sterile saline followed by hydrocolloid dressing was performed. If the condition deteriorated to a necrotic ulcer, a plastic surgeon would be consulted for further treatment.

2.6. Statistical analysis

The data were classified into pre- and postprotocol groups for comparison. Categorical variables were analyzed by the Chi-square or Fisher's exact tests. Student *t* test was used to analyze continuous variables with normal distribution, and the Mann–Whitney *U* test for continuous variables with skewed distribution. Logistic regression was carried out to determine the risk factors for nasal trauma (duration of use of NCPAP, NICU stay, and structured nursing protocol) identified by univariate analysis with $p < 0.05$ as independent variables. The potential confounders considered in the logistic regression were infant sex, parity, gestational age, and birth weight. SPSS version 12.0 (SPSS Inc., Chicago, IL, USA) was used for data manipulation and statistical analysis. All tests were two tailed, and the significance threshold was fixed at 0.05.

3. Results

During the quality improvement project, a total of 59 medical staff in the NICU were involved. Although NCPAP therapy was the routine care in our NICU for > 15 years, the

Please cite this article in press as: Chen C-Y, et al., Quality Improvement of Nasal Continuous Positive Airway Pressure Therapy in Neonatal Intensive Care Unit, Pediatrics and Neonatology (2016), http://dx.doi.org/10.1016/j.pedneo.2016.04.005

Table 1 Structured nursing protocol for nasal continuous positive airway pressure therapy.

1. Installation
   (i) Monitor the heart rate, oxygen saturation, and respiratory rate.
   (ii) Move the NCPAP cart to bedside; wash hands.
   (iii) Choose nasal prongs of the appropriate size according to body weight: No. 0 for 700 g, No. 1 for 700—1250 g, No. 2 for 1250—2000 g, No. 3 for 2000—3000 g, and No. 4 for >3000g.
   (iv) Take the NCPAP fixation kit of the chosen size, precut Velcro and DuoDerm; assemble properly.
   (v) Suction airway before application if necessary.
   (vi) Use swab with sterile saline to gently clean and moisten nasal cavities.
   (vii) Put on the hat.
   (viii) Moisten the nasal prongs thoroughly with lubricant, and then place them curved side down into the infant's nose. The clipped DuoDerm should stay closely between the nasal prong and the nares.
   (ix) Keep a small space between the tip of the septum and the bridge between the prongs (around 0.2—0.3 cm).
   (x) Attach the prongs to the tubing & secure tubing to the hat with paper tape.
   (xi) Fix the tubing straight through incubator porthole by clamp to prevent stretching.
2. Maintenance
   (i) Check the oxygen and ventilator setting. If respiratory condition is stable, wean patients from NCPAP to nasal cannula as tolerated.
   (ii) Be gentle and avoid unnecessary airway suction. The suction pressure should be 80—100 mmHg.
   (iii) Avoid excessive flexion, extension, or rotation of the head and neck; check the position and nasal prongs every hour without stretching the skin or putting undue pressure on the nares.
   (iv) Remove DuoDerm in the morning during bathing and assess the nasal skin integrity closely.
   (v) If air leak is noted, check for any dislodgement in tubing or adjust the position of the prongs first; may try to keep a pacifier in the mouth to close the mouth. In case of persistent air leak, use an elastic chin strap to keep the chin in position.

NCPAP = nasal continuous positive airway pressure.

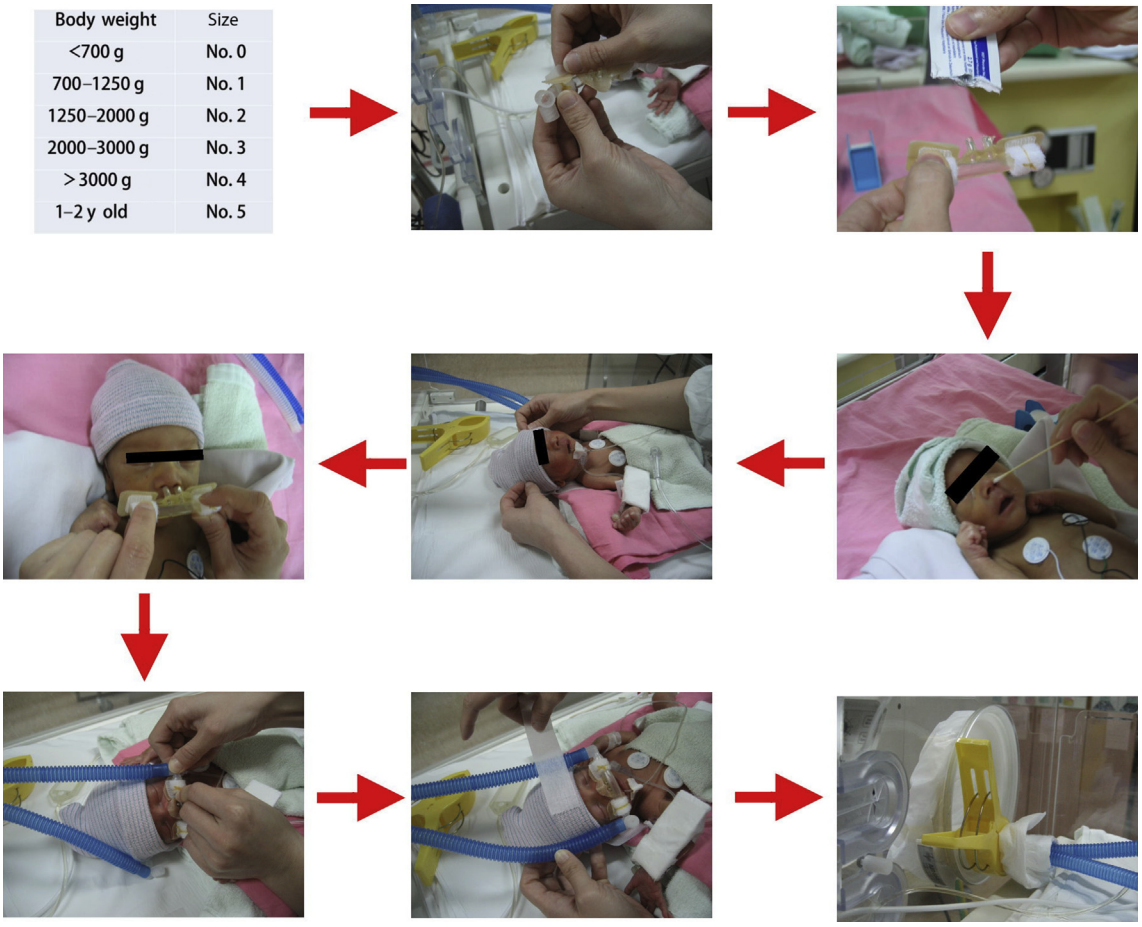

Figure 2 Step-by-step illustration of the installation of nasal continuous positive airway pressure therapy.

Please cite this article in press as: Chen C-Y, et al., Quality Improvement of Nasal Continuous Positive Airway Pressure Therapy in Neonatal Intensive Care Unit, Pediatrics and Neonatology (2016), http://dx.doi.org/10.1016/j.pedneo.2016.04.005

mean score of the first questionnaire before the formal NCPAP education was only 69.2 points. Inaccurate knowledge was most frequently encountered in cases of choosing nasal prongs of the correct size (54.3% error), setting of NCPAP (38.6% error), and possible complications (38.6% error). After serial education classes including lectures and small group discussions, the repeated test 2 months later revealed that the mean scores increased to 98.3 points. The basic knowledge of NCPAP among medical staff could greatly be improved by formal education classes.

From October 2005 to November 2006, NCPAP therapy was initiated in a total of 113 infants during daytime. Eighty-one of them (71.7%) received NCPAP therapy within 24 hours of birth, and the most common diagnoses were respiratory distress syndrome (21.2%), transient tachypnea of the newborn (14.2%), infection or sepsis (13.3%), and perinatal aspiration syndrome (9.7%). The others ($N = 32$, 28.3%) received NCPAP as postextubation support. Of the 113 infants, 31 were enrolled before the implementation of the structured nursing protocol and were in the preprotocol group, and 82 were in the postprotocol group. Clinical characteristics of the pre- and postprotocol groups are shown in Table 2. There was no statistically significant difference in sex, body weight, gestational age, Apgar score, duration of NICU stay, or delivery method between the groups. The frequency of nasal trauma decreased significantly in the postprotocol group (45.2% vs. 19.6%, $p = 0.006$).

To evaluate the effect of the mobile NCPAP cart and structured nursing protocol in NCPAP setup, the durations of preparation and application of NCPAP therapy were measured. From January 2006 to March 2006, 17 episodes were measured before protocol implementation. The mean durations were 520 seconds for preparation and 468 seconds for application. Most of this time was spent on gathering required materials at the bedside, and cutting DuoDerm and Velcro to an appropriate size and shape. In the majority of the patients, appropriate NCPAP support was initiated more than 15 minutes after the decision of therapy was made. After the NCPAP cart and written nursing protocol were implemented in April 2006, 38 episodes were evaluated when NCPAP therapy was initiated in the first 4 months. The mean duration of time required for completing the preparation dramatically decreased to 72 seconds, and that for application also reduced to 200 seconds. Another 16 episodes were recorded 6–8 months after implementation to evaluate the maintenance effect. The mean durations for preparation and application were even shorter at 62 seconds and 172 seconds, respectively. The new strategy of a NCPAP cart improved the efficacy when setting up NCPAP therapy.

Complications in the subgroups of extremely low birth weight (ELBW) infants (birth weight $<$ 1000 g) and non-ELBW infants (birth weight $\geq$ 1000 g) are shown in Table 3. The incidence of nasal hyperemia was significantly decreased in non-ELBW infants, but this was not true of nasal bleeding and ulceration. More latent nasal trauma was discovered in the subgroup of ELBW infants (average, 13.1 $\pm$ 7.1 days after the application of NCPAP) than non-ELBW infants (9.7 $\pm$ 7.1 days). Recovery from trauma was also quicker in larger infants (4.6 $\pm$ 3.1 days vs. 2.1 $\pm$ 1.0 days). In the pre- and postprotocol groups, there was no difference in the interval between trauma and application of NCPAP, and the recovery time.

By univariate analysis, the potential risk factors of nasal trauma included gestational age, birth weight, duration of NICU stay, and lack of use of the structured NCPAP nursing protocol (Table 4). Logistic regression analysis showed the most significant risk factors for nasal trauma were duration of NCPAP use (odds ratio: 1.08, 95% confidence interval: 1.01–1.15, $p = 0.04$) and the lack of use of the structured nursing protocol (odds ratio: 0.09, 95% confidence interval: 0.01–0.77, $p = 0.03$).

Table 2 Clinical characteristics and incidence of nasal trauma in infants who received NCPAP therapy.

	Preprotocol group ($n = 31$)	Postprotocol group ($n = 82$)	p
Male	22 (80.0)	54 (65.9)	0.6
Birth weight (g)	1930.1 $\pm$ 928.0	1884.3 $\pm$ 884.1	0.8
Gestational age (wk)	32.4 $\pm$ 4.9	32.2 $\pm$ 4.6	0.81
Apgar score at 1 min	6.5 (5–8)	8 (7–9)	0.88
Apgar score at 5 min	7 (7–8)	9 (8–9)	0.83
NICU stay (d)	33.4 $\pm$ 38.9	25.6 $\pm$ 25.6	0.21
Vaginal delivery	6 (19.4)	23 (28.0)	0.34
Nasal trauma	14 (45.2)	16 (19.6)	0.006

Data are presented as n (%), n (range), mean $\pm$ standard deviation.
NCPAP = nasal continuous positive airway pressure; NICU = neonatal intensive care unit.

4. Discussion

The beneficial effect of early NCPAP therapy for preterm infants has been demonstrated in a number of multicenter randomized control trials,[1–3,5,8–11] and in most of them NCPAP was initiated within 15 minutes after delivery. Although it is feasible to start NCPAP in the delivery room, only a few studies described the practical aspects in detail.[6,12,13] Early stabilization is important when managing just born preterm infants; thus, how to initiate NCPAP application successfully within minutes is a key issue. In the quality improvement report, we shared our new idea of a mobile NCPAP cart with prepacked NCPAP fixation kits to shorten the duration of NCPAP setup. The cart could be moved to the bedside or delivery room quickly with all required equipment for NCPAP, and the prepared kits saved the collection time. It is easy and practical, and does not increase cost. In our experience, the NCPAP cart with prepacked fixation kits may significantly improve the application process of NCPAP, initiate respiratory therapy earlier, and improve outcomes of preterm infants.

Nasal trauma is one of the most common complications of NCPAP therapy. The incidence ranges from 15% to 60% in the neonatal population.[14–17] Nasal trauma occurred mainly at the medial aspect of the nostrils where the nasal prongs or the carrying crossbar exerted pressure on the nasal septum. Without appropriate care, it could progress to permanent deformity.[15,17–19] In our data, the average

Please cite this article in press as: Chen C-Y, et al., Quality Improvement of Nasal Continuous Positive Airway Pressure Therapy in Neonatal Intensive Care Unit, Pediatrics and Neonatology (2016), http://dx.doi.org/10.1016/j.pedneo.2016.04.005

Table 3 Incidence of nasal trauma by birth weight.

	<1000 g			≥1000 g		
	Preprotocol (n = 5)	Postprotocol (n = 15)	p	Preprotocol (n = 26)	Postprotocol (n = 67)	p
Nasal trauma	4 (80.0)	8 (53.3)	0.60	10 (38.5)	8 (11.9%)	0.007
Hyperemia	3 (60.0)	7 (46.6)	1.00	7 (26.9)	5 (7.4%)	0.03
Bleeding	2 (40.0)	4 (26.6)	0.61	3 (11.5)	3 (4.4%)	0.34
Ulceration	0 (0.0)	0 (0.0)	—	1 (3.8)	0 (0.0%)	0.28
Days after NCPAP	23.7 ± 21.7	13.1 ± 7.1	0.21	7.1 ± 11.8	9.7 ± 7.1	0.71
Duration (d)	3.0 ± 1.6	4.6 ± 3.1	0.36	2.3 ± 1.4	2.1 ± 1.0	0.81

Data are presented as n (%) or mean ± standard deviation.
NCPAP = nasal continuous positive airway pressure.

Table 4 Comparison of risk factors for nasal trauma after continuous positive airway pressure.*

	Trauma (n = 30)	No trauma (n = 83)	p	Adjusted odds ratio (95% CI)
Gestational age (wk)	29.7 ± 4.3	33.1 ± 4.5	0.001	—
Birth weight (g)	1449.3 ± 776.0	2058.7 ± 880.4	0.006	—
Nursing protocol	16 (53.3)	66 (79.5)	0.006	0.29 (0.01–0.77)
Smaller prong size†	17 (56.7)	41 (49.4)	0.53	2.40 (0.39–14.15)
NICU stay (d)	45.7 ± 34.2	21.3 ± 25.3	0.001	0.99 (0.94–1.04)
Duration of NCPAP (d)	37.4 ± 16.0	9.2 ± 12.9	0.002	1.06 (1.01–1.15)

Data are presented as n (%) or mean ± standard deviation.
CI = confidence interval; NCPAP = nasal continuous positive airway pressure; NICU = neonatal intensive care unit.
* Logistic regression adjusted by birth weight and gestational age.
† The reference is according to the sizing chart of the Hudson RCI® system.

incidence of nasal trauma under the written protocol was 19.6%, and no nasal deformity developed. Interventions to reduce compression pressure by nasal prongs are of primary importance. Some studies suggest the use of nasal dressings with the aim of minimizing nasal trauma.[14,15,20] The addition of a hydrocolloid patch with two small holes could provide a better seal to prevent leakage, and it protected the nose from direct friction with nasal prongs. However, one recent study demonstrated that the use of protective dressings was not associated with decreased nasal trauma for infants on NCPAP.[21] The most important issue was a stable fixation method. In our experience, implementation of a written protocol standardized and improved NCPAP practice, therefore decreasing the incidence of nasal trauma, except in the group of ELBW patients. Premature infants have immature skin and often require respiratory support for longer periods, both of which increase the risk for nasal trauma. The patients who developed nasal trauma during the study period tended to have smaller gestational age and birth weight; this finding was compatible with those of the reported studies.[15] Preventing nasal trauma during NCPAP therapy is still one of the biggest challenges, especially in ELBW patients.

There are some limitations in the interpretation of the current data. Since the researchers and medical staff of this study were not blinded, observation bias might have influenced the estimation. The incidence of nasal trauma might be overestimated, especially for mild nasal hyperemia in smaller babies. This may partly explain the relatively high incidence of nasal hyperemia in infants with a birth weight of < 1000 g, and it may account for why there was no significant improvement of nasal trauma after implementation of the protocol. Under the same bias, preparation and application durations may have been underestimated since the staff were more familiar with the process of initiation of NCPAP therapy. The surveillance of research nurses during the study period also facilitated the application of NCPAP, which may further influence the effect of protocol implementation. The actual effect of the protocol and mobile cart could be evaluated during the follow-up period. The rate of nasal trauma and the durations of preparation and application remained low when re-evaluation was performed 6–8 months after the study period, and the system still functioned well thereafter. Thus, the mobile cart with a well-written protocol could improve the quality of NCPAP therapy.

5. Conclusion

The mobile NCPAP cart with prepacked fixation kits is an inexpensive and practical way to improve the efficacy of NCPAP therapy. A written nursing protocol could decrease the incidence of nasal trauma in infants admitted to the NICU, except for those with a lower birth weight. The required durations of preparation and application were made shorter and the incidence of nasal skin trauma was reduced by standardized nursing care. Smaller gestational

Please cite this article in press as: Chen C-Y, et al., Quality Improvement of Nasal Continuous Positive Airway Pressure Therapy in Neonatal Intensive Care Unit, Pediatrics and Neonatology (2016), http://dx.doi.org/10.1016/j.pedneo.2016.04.005

age, lower birth weight, and prolonged NCPAP use remained the major risk factors for the development of nasal skin trauma.

Conflicts of interest

The authors have no conflicts of interest to disclose.

Acknowledgments

The authors thank Professor, Jen-Tien Wung, Columbia University College of Physicians and Surgeons, New York whose particular and ongoing interest in the presentation, investigation, and clinical practice of nasal continuous positive airway pressure is the basis for this paper. The authors also thank the staff of the National Taiwan University children Hospital, Taipei, Taiwan neonatal intensive unit and the nurses, junior doctors, and consultant colleagues involved in the referral and care of these infants. The parental support for this study is greatly appreciated.

References

1. Morley CJ, Davis PG, Doyle LW, Brion LP, Hascoet JM, Carlin JB, et al. Nasal CPAP or intubation at birth for very preterm infants. *N Engl J Med* 2008;**358**:700—8.
2. SUPPORT Study Group of the Eunice Kennedy Shriver NICHD Neonatal Research Network, Finer NN, Carlo WA, Walsh MC, Rich W, Gantz MG, et al. Early CPAP versus surfactant in extremely preterm infants. *N Engl J Med* 2010;**362**:1970—9.
3. Dunn MS, Kaempf J, de Klerk A, de Klerk R, Reilly M, Howard D, et al. Randomized trial comparing 3 approaches to the initial respiratory management of preterm neonates. *Pediatrics* 2011;**128**:e1069—76.
4. Badiee Z, Naseri F, Sadeghnia A. Early versus delayed initiation of nasal continuous positive airway pressure for treatment of respiratory distress syndrome in premature newborns: a randomized clinical trial. *Adv Biomed Res* 2013;**2**:4.
5. Committee on Fetus and Newborn, American Academy of Pediatrics. Respiratory support in preterm infants at birth. *Pediatrics* 2014;**133**:171—4.
6. Bonner KM, Mainous RO. The nursing care of the infant receiving bubble CPAP therapy. *Adv Neonatal Care* 2008;**8**:78—95. quiz 96—7.
7. Lund CH. Nursing care. In: Goldsmith JP, Karotkin EH, editors. *Assisted ventilation of the neonate*. 5th ed. St Louis, MO: Elsevier/Saunders; 2011. p. 126—39.
8. Sandri F, Ancora G, Lanzoni A, Tagliabue P, Colnaghi M, Ventura ML, et al. Prophylactic nasal continuous positive airways pressure in newborns of 28—31 weeks gestation: multicentre randomised controlled clinical trial. *Arch Dis Child Fetal Neonatal Ed* 2004;**89**:F394—8.
9. Rojas MA, Lozano JM, Rojas MX, Laughon M, Bose CL, Rondon MA, et al. Very early surfactant without mandatory ventilation in premature infants treated with early continuous positive airway pressure: a randomized, controlled trial. *Pediatrics* 2009;**123**:137—42.
10. Finer NN, Carlo WA, Duara S, Fanaroff AA, Donovan EF, Wright LL, et al. Delivery room continuous positive airway pressure/positive end-expiratory pressure in extremely low birth weight infants: a feasibility trial. *Pediatrics* 2004;**114**:651—7.
11. Tapia JL, Urzua S, Bancalari A, Meritano J, Torres G, Fabres J, et al. Randomized trial of early bubble continuous positive airway pressure for very low birth weight infants. *J Pediatr* 2012;**161**:75—80.e1.
12. McCoskey L. Nursing care guidelines for prevention of nasal breakdown in neonates receiving nasal CPAP. *Adv Neonatal Care* 2008;**8**:116—24.
13. Squires AJ, Hyndman M. Prevention of nasal injuries secondary to NCPAP application in the ELBW infant. *Neonatal Netw* 2009;**28**:13—27.
14. do Nascimento RM, Ferreira AL, Coutinho AC, Santos Veríssimo RC. The frequency of nasal injury in newborns due to the use of continuous positive airway pressure with prongs. *Rev Lat Am Enfermagem* 2009;**17**:489—94.
15. Fischer C, Bertelle V, Hohlfeld J, Forcada-Guex M, Stadelmann-Diaw C, Tolsa JF. Nasal trauma due to continuous positive airway pressure in neonates. *Arch Dis Child Fetal Neonatal Ed* 2010;**95**:F447—51.
16. Fujii K, Sugama J, Okuwa M, Sanada H, Mizokami Y. Incidence and risk factors of pressure ulcers in seven neonatal intensive care units in Japan: a multisite prospective cohort study. *Int Wound J* 2010;**7**:323—8.
17. Robertson NJ, McCarthy LS, Hamilton PA, Moss AL. Nasal deformities resulting from flow driver continuous positive airway pressure. *Arch Dis Child Fetal Neonatal Ed* 1996;**75**:F209—12.
18. Yong SC, Chen SJ, Boo NY. Incidence of nasal trauma associated with nasal prong versus nasal mask during continuous positive airway pressure treatment in very low birthweight infants: a randomised control study. *Arch Dis Child Fetal Neonatal Ed* 2005;**90**:F480—3.
19. Jatana KR, Oplatek A, Stein M, Phillips G, Kang DR, Elmaraghy CA. Effects of nasal continuous positive airway pressure and cannula use in the neonatal intensive care unit setting. *Arch Otolaryngol Head Neck Surg* 2010;**136**:287—91.
20. Günlemez A, Isken T, Gökalp AS, Türker G, Arisoy EA. Effect of silicon gel sheeting in nasal injury associated with nasal CPAP in preterm infants. *Indian Pediatr* 2010;**47**:265—7.
21. Collins CL, Barfield C, Horne RS, Davis PG. A comparison of nasal trauma in preterm infants extubated to either heated humidified high-flow nasal cannulae or nasal continuous positive airway pressure. *Eur J Pediatr* 2014;**173**:181—6.

Please cite this article in press as: Chen C-Y, et al., Quality Improvement of Nasal Continuous Positive Airway Pressure Therapy in Neonatal Intensive Care Unit, Pediatrics and Neonatology (2016), http://dx.doi.org/10.1016/j.pedneo.2016.04.005